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Network Issues

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Executive Summary

At the present crossroads in moving "Towards Real Time," the IGS finds itself (as always) in a position to learn from its past, address its present needs and anticipate future directions. In this paper we review the IGS network as it currently exists and its effectiveness in supporting the IGS suite of precise products. We note that modernized GPS / GNSS signals will affect all aspects of the IGS and that the IGS must begin to anticipate the necessary steps required to handle a modernized GPS signal as well as other (new) GNSS signals. The importance of careful archival of site meta data as well as GPS data for future usage, cannot be understated. Also addressed are the IGS' relationships to the industry which supplies equipment to the network, the reporting of IGS network performance, the evolution of data exchange formats and the (once fanciful) notion that there may be too many IGS sites in some areas of the world.

A number of recommendations are made, the principal ones being:

A) GPS / GNSS Modernization: The IGS must assess the implications of GPS modernization and new GNSS technologies on the delivery of IGS products; based on this the IGS must consider the optimal means for ensuring a seamless transition to the modernized system(s).

B) Associate Regional Networks: The IGS should consider the concept of Associate Regional Networks (ARN) for those areas where agencies operate stations that meet the IGS criteria but where station density is greater than that required by the IGS. Data from ARN stations that are required globally would continue to be submitted to IGS data centers.

C) Instrumentation / Site Changes: In order to minimize jumps at Global Reference Stations a set of best practices is encouraged, including clear guidelines for equipment and site changes; any change in site coordinates whether due to instrument changes, seismic activity or other should be carefully noted and published.

D) Data Exchange Format and Industrial Relations: The IGS should establish a joint Task Force with GPS manufacturers to coordinate the evolution and international acceptance of the RINEX format, encourage standardization of meta-data nomenclature and coordinate any future data exchange formats.

E) Station Metrics: The IGS should examine the current station performance metrics and determine required changes; consider efficient methods of compiling and communicating station events or periods which may challenge present and future users' analysis; determine ways to improve any deficiencies in communicating station quality issues between AC's, the Coordinators (ACC, Ref. Fm. Coordinator, and NC), station operators, and outside users.

1.0 Background

As the IGS community moves towards the delivery of real time data and products we face not only the task of meeting the real time goals but also the challenges of a modernized GPS constellation, the renewed strength of the GLONASS system and the advent of the Galileo system. The integrity of the data and products provided by the IGS will be increasingly reliant on a robust infrastructure consisting of improved (real time) communication from tracking stations, upgrade of existing station instrumentation to handle the modernized satellite constellation(s) and provision of data and station quality control statistics in near-real time. The data exchange standards will have to be improved in order to meet the real time applications, specifically the requirements for real-time dissemination of meta-data and, perhaps more importantly, the flagging of site reconfigurations (instrumentation, antenna, height of antenna, etc.), with real time alacrity.

IGS stations presently provide continuous tracking of the GPS constellation employing geodetic quality, dual frequency receivers. IGS stations have to meet the requirements as set forth in: "Standards for IGS Stations and Operational Centers, Version 1.3 (9 February, 1999)", (http://igscb.jpl.nasa.gov/network/guide_igs.html). With GPS modernization starting as soon as 2003 it will be necessary to review this document and define the operating requirements for stations contributing data to the IGS. At the same time it is essential to review the current network in terms of spatial distribution of sites, station / agency capability to provide data at various sampling rates and delivery latencies (real time, 1 hr, 24 hr, high rate, 30 sec, etc.) in order to determine the network requirements for the future. While we are moving toward real time delivery of data we must continue to ensure that we do not compromise existing standards and products. Certainly in the near term there will be a continued requirement for the 24-hour data sets and 1-hour data sets. There may be justification to look at intermediate data delivery (e.g. 4-hr, 6-hr, 12-hr) as the GPS satellite constellation undergoes change and as new systems come on-line.

All IGS products are and will always be reliant on timely data delivery: The IGS Final Products are primarily reliant on the 24-hour data stream; the IGS Rapid and Ultra-Rapid Products are primarily reliant on the 1-hour data streams.

1.1 Summary of IGS Products

IGS Final Products	IGS Rapid Products	IGS Ultra Rapid Products
GPS Ephemeris	GPS Ephemeris	GPS Ephemeris
GLONASS Ephemeris		
Satellite & Station Clocks	Satellite & Station Clocks	Satellite Clocks
Station Coordinates		
Station Velocity		
Polar Motion	Polar Motion	
Polar Motion Rates	Polar Motion Rates	
Length-Of-Day	Length-Of-Day	
Zenith Troposphere		
Ionospheric TEC Grid		

Source: Weber et al

The availability of these, and new products such as the ultra-rapid zenith troposphere delay currently under development, depends directly on the timeliness and quality of the raw satellite observables delivered to the analysis centers. Station changes, as recorded in IGS Site logs (and therefore in the IGS SINEX template), and in the meta-data fields of RINEX headers are critical to the analysis processes. The data and meta-data distribution system currently in place, while not perfect, meets most of the operational objectives of the IGS. The move to near-real time (hourly data) and the planned moved to high rate, real time data will force a re-evaluation of data delivery means.

2.0 GPS Modernization

The GPS constellation is about to undergo its first major upgrade since its inception, an upgrade that will require new instrumentation at reference stations around the world. Each agency which contributes data to the IGS will undoubtedly have to meet not only IGS requirements but also the agency's mandates and the demands of their immediate user groups.

The modernized Block IIR satellites (IIR-M) - 12 in total - will transmit a civil code on the L2 frequency (L2C) commencing as early as 2003. This is part of a broader plan to modernize the GPS signal structure to include Military code on L1 and L2 frequencies, add a new frequency in the Aeronautical Radio Navigation Service (ARNS) band, the L5 frequency (Block IIF satellites), in addition to the aforementioned new civil code L2C. Initially envisioned as a C/A code on L2, the new L2C code will in fact be an "improved" C/A code opening up the door for improved tracking and new applications. (For a full description of the L2C and Block IIR-M, Block IIF satellites see Fontana et al, (1) & (2)).

The first Block IIR-M satellite is scheduled to be launched in 2003 (Fontana, et al (1)). The projected schedule, to be confirmed, shows the first Block IIF launch date as 2005.

By 2011 the GPS constellation will have 28 satellites with full L2C capability of which 18 satellites will have L5.

The implication of these changes to the IGS will be far reaching. For the first time in the history of the IGS we will be forced to coordinate a systematic upgrade of the IGS infrastructure including IGS sites (receivers, antennas, etc.), downstream data handling and processing (data conversion, quality control and analysis) software. As the L5 is implemented new antennas will appear on the market, requiring calibration, and the downstream effect on apparent phase centers at longstanding reference frame stations and the IGS 'Global Stations' will have to be monitored.

2.1 Issues / questions to discuss wrt L2C and L5:
IGS Network Upgrades:
- Required Changes to IGS Network required for:
    - IGS 'Global Stations'
    - 24-hr sites
    - Near-real time sites (1-hr data)
    - Near-real time sites (15min files, 1 Hz data)
    - Real time sites
- Effect on IGS Products
    - Near term;
    - Long Term
- Effect on data handling / analysis systems:
    - RINEX standard / changes to converters
    - Data validation software (TEQC, GIMP, GPSPACE, ?.)
    - Analysis software (Bernese, GIPSY, GAMIT, ?.)
- Required Changes to Site Logs
- Coordination of upgrades, standardization for uniform data / product flow;

The mandates of individual agencies may in some instances drive the upgrades of IGS sites to equipment supporting modernization. The IGS must therefore prepare for the possibility of modernized data in the IGS stream as new satellites come online, and make recommendations for data handling.

It should be noted that the "natural" upgrading of stations to modernized equipment may not meet the core requirements necessary to ensure that the IGS continues to meet its goal of providing the highest quality GPS data and products. Once the GPS modernization impact has been assessed and the requirements for stations supporting modernization have been detailed in the "Standards for IGS Stations and Operational Centers" document, the IGS should consider issuing a non-binding call for letters of intent (LOI) to upgrade within a specific time period. Based on the response, the IGS could examine the anticipated global coverage and if necessary, target agencies working in deficient areas with letters of request to support the IGS' first phase of modernization support. Such letters may assist the agencies in approaching funding sources with requests related to modernizing stations.

This process of issuing requests for non-binding LOI's could be utilized for station upgrades foreseen as necessary on a network-wide basis and would secure an initial set of upgraded stations, and thus help coordinate a phased upgrade.

3.0 IGS Station Distribution, Station Classification

As of March 2002 the IGS Network consists of 293 stations, representing some 200+ agencies around the world. Of the 293 stations, 117 are classified as IGS 'Global Stations'- *(see IGS Terms of Reference for definitions)*. These stations are at a minimum producing 30-sec., 24-hour RINEX files.
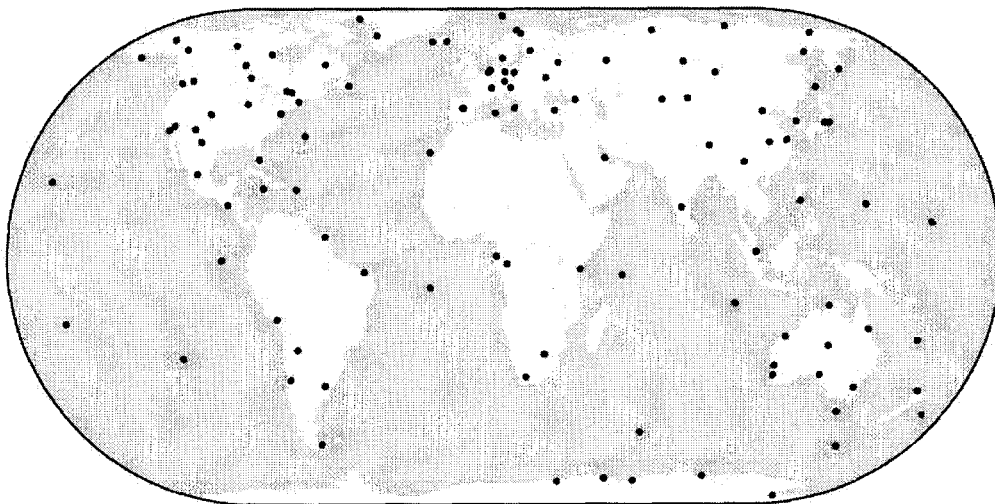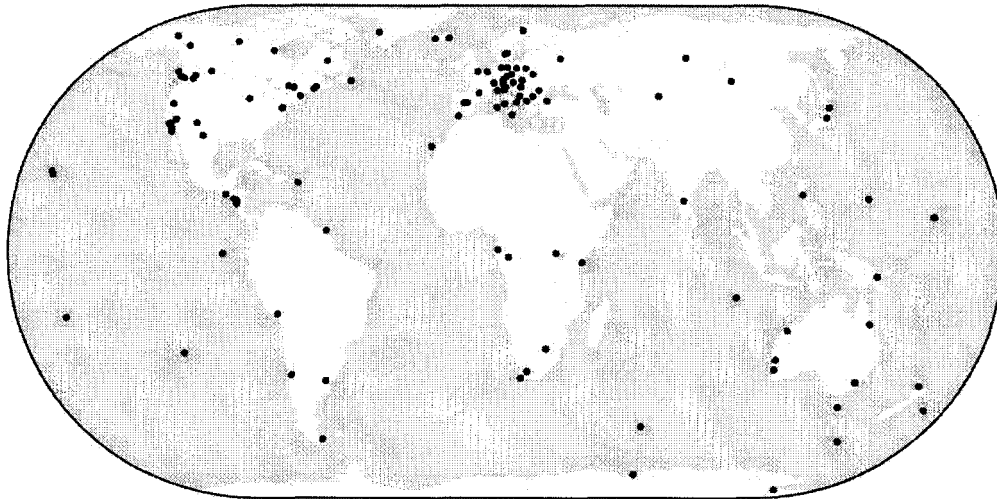


fig. 1 Distribution of IGS 'Global Stations'

In the past 2 years the distribution of IGS 'Global Stations' has improved with new stations in Africa, Asia and S. America coming on line. However from fig. 1 it is evident that there are still some gaps in global coverage.

fig. 2 Distribution of 1-hr IGS Stations

Approximately 90 IGS stations are producing hourly 30-sec. RINEX files - It should be noted that (a) many, but not all, are IGS 'Global Stations' and (b) there are higher concentrations in North America and Europe. Given (a), there may be an insufficient number of IGS 'Global Stations' contributing to the rapid / ultra-rapid products, implying that there may be insufficient consistency between stations used by the AC's for rapid / ultra-rapid products, as compared with stations used for the final products. It also follows from both (a) and (b) that the total number of stations contributing hourly data files is misleading in terms of worldwide coverage when compared to the scenario of an equally distributed network of 90 stations; see fig. 2 for the gaps and concentration(s) in coverage.
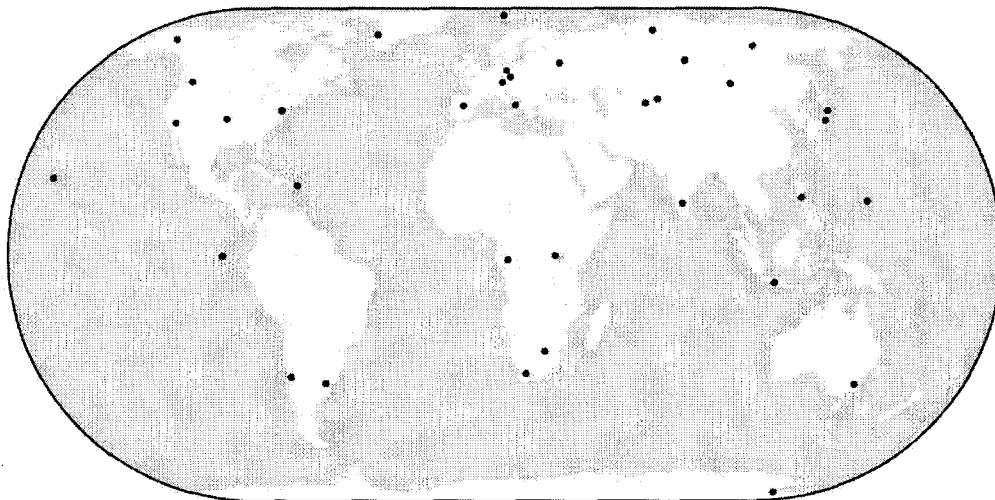
fig. 3 Distribution of IGS Stations providing 1Hz, 15 min files

There are approximately 35 stations providing data in near real-time, through the delivery of 15-minute, 1Hz data files. Agencies currently providing this data stream are GFZ, JPL, ASI (MATE), and GOPE. Approximately two-thirds of these are IGS 'Global Stations'. Other sites / agencies have demonstrated the capability to produce 1 Hz data, either in real-time or in near real-time.

3.1 Issues / questions to discuss wrt IGS Station Distribution, Station Classification:

- Is the current distribution of IGS stations (GPS and GLONASS) sufficient to meet final, rapid and ultra-rapid products?
- What is the minimal distribution of IGS stations required to meet real-time needs? How many of these have to be IGS 'Global Stations'?
- What is the optimal distribution of IGS stations required to meet real-time needs? How many of these have to be IGS 'Global Stations'?
- Of the stations / agencies currently providing, or with demonstrated capability to provide 1Hz data, which are willing / able to contribute to the IGS real-time delivery of data?
- What are the implications for the IGS Network in terms of the new GPS satellite signal commencing 2003?
  - o Should the IGS set targets for the upgrade of current IGS stations to handle L2C and L5 w.r.t.:
    - Timeframe;
    - Coverage (IGS 'Global Stations', 1 hour sites, real time sites);
- Is there a requirement for intermediate data delivery (4-hr, 6-hr, 12-hr)?

Once the IGS has determined the requirements for station distribution world-wide to meet the requirements to produce the varied IGS products and data streams, it will be necessary to address the issue of stations which are part of regional networks and / or are redundant to primary IGS objectives. The IGS as an organization values its inclusive and voluntary nature, and up to now has accepted any proposed station meeting the technical requirements. In some instances, this benefits global geodesy if only by acknowledging the operation of a quality permanent station, which may lead to increased funding and participation of the host agency. However, today we find quite adequate coverage in many areas of the world. A certain amount of redundancy is desirable to guard against the impact of unforeseen downtime of any given station, but at some level, adding further stations may serve only to increase user confusion. The IGS must somehow balance the conflicting goals of inclusivity and providing a globally relevant data set of the highest precision.

It is proposed that the IGS consider the concept of Associate Regional Networks, networks which operate stations that meet the IGS criteria but at a density greater than that required by the IGS. These networks are recognized as being an integral part of the IGS but are linked at the Network level rather than at the station level. They would only submit data to IGS data centers from those stations that are required globally. Data and site logs from all their stations meet IGS standards and are made available and archived at the Associate Regional Network Data Center. Should a regional station later become globally significant, it would then be easy to absorb it into the main IGS data and meta-data distribution system. The principal IGS web sites (Central Bureau, CDDISA, IGN, EUREF, etc.) would provide links to Associate Regional Network web sites, ftp locations, contact information, etc. In this way, stations that meet all IGS requirements receive the recognition they deserve by means of the IGS Associate Regional Network label, without unnecessarily complicating the IGS Network and data distribution system.

A panel should be formed to consider the utility of proposed new stations in areas already hosting existing stations. This group should consider the need for redundancy in the region as well as the presence of desirable co-located equipment such as other space geodesy instruments, meteorological instrumentation, tide gauges, and so on. As quick action would be desired, this group should act by email and should ordinarily take a decision based on a minimum number of agreeing members and within one week to avoid stalling the process should a few members be unavailable for a period of time. The panel would need representation from at minimum, several ACs and several Working Groups and Pilot Projects.

IGS Associate Application Networks might also be considered to recognize specialized networks, supporting a given area of investigation rather than a particular region, if admitting all the member sites to the IGS Network would be undesirable.

- Equipment never before used in the IGS should be avoided until tested and well understood by IGS ACs

Once these are agreed upon, a letter to RefFm sites should acknowledge the special responsibility of maintaining a RefFm site and request the station operators' assistance in observing these recommendations to preserve the integrity of long-term time series.
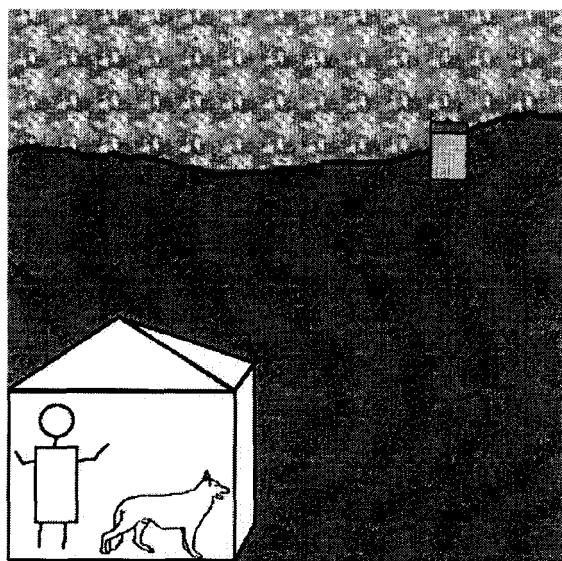
fig 5 - The IGS Reference Frame site of the future:
The equipment's job is to take the data.
The person's job is to feed the dog.
The dog's job is to bite the person if he tries to touch the equipment.

4.1 Issues / questions to discuss wrt Reference Frame Station Issues:
- How should jumps be recorded (to be examined jointly with RFWG)?
- What is to be done if a jump is inconsistently observed among the ACs?
- What if nonlinear motion is observed?
- What is the most efficient way to introduce new types / models of instrumentation to RefFm stations - (guidelines, overlaps, calibrations, etc.)?

4.0 Reference Frame Station Issues

Jumps in calculated IGS station positions, particularly those not removed by applying known factors such as antenna (and therefore phase center) changes, are of concern to the ability to support long-term, high-accuracy geodesy. This is of particular trouble to Reference Frame (RefFm) sites. Figure 4 shows the vertical component of the combined solution at station HOFN, with a large offset coincident with a radome and antenna change in late 2001. Such behavior would be especially troublesome at a Reference Frame (RefFm) site.
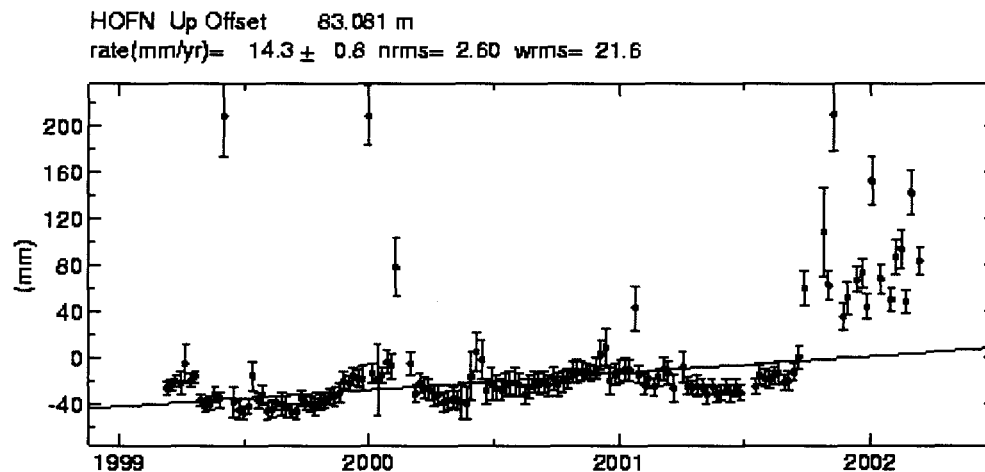
HOFN Up Offset   83.081 m
rate(mm/yr)= 14.3 ± 0.8 nrms= 2.60 wrms= 21.6

fig. 4 IGS SINEX combination data as graphed on MIT/GPSG's web page

We can imagine 4 classes of station position jumps remaining after all correct meta-data has been applied:
1. Those not concurrent with any known event
2. Those concurrent with natural, unavoidable events such as earthquakes
3. Those concurrent with, but whose magnitudes are not explained by, equipment changes
4. Those concurrent with related site events such as tree trimming

To serve long-term geodesy optimally, the IGS should strive to document all types thoroughly, and further, minimize the impact & occurrences of types 3 and 4, most especially at RefFm sites. They must continue to be documented in all cases, but we may consider formalizing the classification as a RefFm site in an attempt to minimize their frequency. A set of best practices crucial for RefFm sites should be drawn up, perhaps starting with:
- Equipment should be changed only when there is a clear necessity and benefit
- Planned equipment changes should have a period of at least 1 month overlap
- Site changes, e.g. construction of buildings in the vicinity of the RefFm monument, should be avoided as much as possible
- Equipment known to produce poorly understood behavior in calculated station positions, e.g. conical radomes, should be avoided

5.0 Meta-Data Update in Real Time

Meta-data (receiver, firmware, antenna, antenna offsets, etc.) changes are presently announced via 'IGSMAIL' distribution with site logs updated at the Central Bureau; the SINEX template, (generated daily at the CB and used by the AC's as input parameters), consequently reflects the newly submitted information. In the real-time world this will not be sufficient as station changes could have a severe impact on real time analysis of data. The question becomes how best to update the user community of changes at real-time sites. The solution must support timely notification as a user acquires the stream; for example, if a station change has occurred while users were offline, they must become aware of the change before processing the data stream. Similarly, real-time analysis streams must be cognizant of, and take into account, station changes as they occur. Some options to consider:

- Real-Time data stream provides meta-data: The meta-data need not be sent at the same rate as the GPS data. Instead periodic updates, or "header" messages at a slow repeat rate is suggested (e.g. station meta-data update every 5, 15, (?), minutes). The advantage of this approach, as with the current RINEX standard, is that the meta-data is contained within the GPS data flow / files.
- Provide a pointer to the fact that new meta-data is available (from a defined location). A "station setup counter" can reference the equipment configuration. If the configuration (receiver/antenna/height/etc) is changed, the counter is incremented and users (programs) know to go seek the details (as previously defined). For instance, if the stream passed "3.3,4.4" as the "station setup counter", the AC would know the current setup is as in site log sections 3.3 (receiver) and 4.4 (antenna). If the string changed to "3.4,4.4" the AC would know the receiver has changed but the antenna has not and deal with it accordingly. This is only an example drawing on the current use of site logs for illustration of how the stream could provide meta-data information without providing the meta-data itself. The disadvantage(s) of this approach would be the reliance on external data sources, (i.e. site logs), which in the real world would occasionally be unreachable, e.g. due to a network outage other than at the site; in addition correlating the "station setup counter" with (for example) a specific site log or SINEX template format, places constraints on future development of these formats.
- Dispense a complete set of station configuration information to the user at the time of data stream acquisition. On station reconfiguration, dispense that information to all currently subscribed listeners.

5.1 Issues / questions to discuss wrt Meta-Data Update in Real Time:
Data / Meta-Data:
- Are current GPS / GLONASS data rates sufficient to meet present / new products?

- What is the target latency for:
  - o Real time data?
  - o Near-real time sites (15min files, 1 Hz data)
  - o Near-real time data (1 hr files)?
  - o 24-hr files?
- Is there need / justification to consider intermediate data delivery (e.g. 4-hr, 6-hr, 12-hr)?
- What guidelines do we need to institute for updating of IGS logs and meta-data fields in RINEX headers?
- How do we handle the update of meta-data in real time?

6.0 RINEX Format

The RINEX (Receiver Independent Exchange) format was developed as a means to exchange data between users irregardless of what brand of GPS receiver was used. The most recent version (version 2.10) of the RINEX standard was last updated Jan. 25, 2002. The format consists of six ASCII file types: Observation Data File, Navigation Message File, Meteorological Data File, GLONASS Navigation Message File, GEO Navigation Message File and Satellite and Receiver Clock Date File. The RINEX format has been adopted by most, if not all, manufacturers of GPS / GLONASS receivers / software. It is currently the standard for data exchange within the IGS using the Hatanaka and UNIX "compress" compression schemes. Having said that, not all RINEX generators / readers are necessarily compliant with all aspects of the current standard.

A draft of RINEX version 2.20 was presented at the IGS LEO meeting in Potsdam, in order to accommodate GPS data from LEO satellites. For proposed modifications see: ftp://ftp.unibe.ch/aiub/rinex/rnx_leo.txt .

It is not clear if these proposed changes are compatible with the needs of a modernized GPS system and whether they have to be re-visited. With the introduction of the Block IIR-M, with L2C code in 2003 and the Block IIF satellites with L5 in 2005, new observables will be added to the data stream. Changes to the RINEX standard require changes in existing computer programs that either generate and/or read RINEX files. Changes also have to be backwards compatible, so that new code can still read older files. It must also be recognized that the usage of the RINEX standard extends well beyond the scientific / IGS community. Commercial GPS software uses RINEX data format extensively, some even linking to IGS data centers automatically to retrieve data from the nearest IGS station.

In the short term the RINEX format will have to be changed to allow for the new observables. The IGS should also institute periodic reviews of its procedures to consider whether these are meeting and will continue to meet the IGS goals and objectives appropriately. It may be that another exchange format for the future should be considered, one which is sustainable and easy to extend as new observables and new satellite systems (e.g. Galileo) come on-line. Rather than comparing existing RINEX /

BINEX formats it is suggested that the requirements / specifications for an exchange format be defined and subsequent to that, a solution proposed.

The IGS could coordinate the modification of the RINEX format and the design of a new exchange format, consulting with the major stake holders, including the major manufacturers and software developers *(see also section 7.0 below)*.

6.1 Issues / questions to discuss wrt RINEX Format:

- Who within the IGS should be tasked to work on the next version of the RINEX standard? Is a 'working group' required?
- What is a realistic timeline for RINEX standard upgrade?
- How can we best address the need of a next generation exchange format?
- What is the best way to involve all major stake holders?

7.0 Manufacturer Relations

Information exchange between the IGS and manufacturers of geodetic GPS (and related) equipment is necessary for a number of reasons, including:

- Communication of requirements of IGS station instrumentation
- Communication of equipment capabilities
- Understanding of how proposed IGS changes affect manufacturer equipment and software
- Timely communication of information about equipment, such as appropriate model designations & descriptions, or observables tracked
- Calibration of antenna phase centers.

Immediate examples are (a) the proposed changes to the RINEX format and introduction of new formats, and (b) the continual need for agreed upon meta-data nomenclature prior to the deployment of GPS and ancillary instrumentation within the IGS. These issues are of mutual benefit to the IGS, to the manufacturers and to the GPS users at large who are increasingly using more IGS products and data sets.

To achieve these goals, an "IGS Instrument Panel" should be formed. Vendors whose products are used in the IGS should appoint to the Panel a representative who is committed to swiftly and effectively providing needed information to the IGS. The Panel would also provide a link by which matters such as proposed format changes and future station needs may be discussed. A panel such as this could facilitate internationally agreed upon exchange formats and meta-data nomenclature standards (as for example found in the IGS Receiver / Antenna Table: ftp://igscb.jpl.nasa.gov/igscb/station/general/rcvr_ant.tab).

8.0 IGS Metrics

IGS Station Performance metrics must answer many questions from different customers:
- Station operators:
    - How is my site doing?
    - How well does my site support the IGS?
    - Is there some way I might improve my site, even given local infrastructure constraints?
- Network Coordinator:
    - What sites need attention?
    - What areas need more sites, more sites with certain characteristics, or more sites for tolerance against occasional site failure?
- Users:
    - What site(s) should I use for my analysis?
    - Are there any known problems with site xxxx within this time period?

Answering all of these in a quick, easy-to-use manner may imply multiple reports or at least multiple sorts of data. Graphical and alphanumeric presentations each have their own strengths in communicating data and a combination of both should be considered. Answering all of these in a quick, easy-to-use manner implies multiple reports or at least multiple sorts of the data.

Potential improvements to the existing IGSNet (ftp://igscb.jpl.nasa.gov/pub/mail/igsnet) reports have been discussed previously, but there has been no clear action defined. Here we examine pros and cons of the existing system as well as some of the alternatives.

IGSNET reports
The Quality score in the IGSNET reports uses engineering data from the JPL AC's IGS analysis:
- Number of valid clock solutions
- Number of phase breaks after editing
- Ratio of number of pseudorange measurements to number of phase measurements
- 3D formal error
- phase & pseudorange rms residuals

PRO: - plenty of actual data relevant to IGS analysis
CON: - Not all of the engineering data is typically available to the public.
- Dependence on the JPL AC
- No data for a given site if the JPL AC does not process it

SINEX combination residuals
PRO: - High relevance to the IGS
CON: - No data for a given site if it is not in the combination

TEQC summaries
PRO: - Easily generated for all sites
CON: - More of a quick look at the signals, rather than heavy-duty geodetic
processing.
- Not able to verify a high correlation between high/low IGSNET Quality scores
and any fields in the teqc summaries.

AG or similar mail-in point positioning runs
PRO: - Could get the same data as currently used in IGSNET Quality scores for any
sites not processed by JPL AC
CON: - Dependence and burden on JPL (or other) AC

8.1 Issues / questions to discuss wrt IGS Metrics:
- What metrics are required by the Station Operators, Network Coordinator and users?
- What changes / improvements are required?
- What tools should be developed and / or adopted by the IGS? - for example are there software tools available that could be incorporated at the station operator level in addition to TEQC?
- Is there a requirement for a publicly available compilation of station "problem" periods? How would this be handled if there is a disagreement on the "problem"? (See also the station event reporting issues of Section 4.1).
- Are there deficiencies in communicating station quality issues between ACs, the Coordinators (ACC, Ref. Fm. Coordinator, and NC), station operators, and outside users?

9.0 Real Time Communication

The delivery of Real-Time GPS data from reference station to Regional Center (RC) and then on to the IGS and other user communities is broken into two components:
- Transfer of GPS data from Reference Station to Regional Network Center
- Transfer of GPS data and meta-data to the IGS and other users.

The transfer, in real time, of GPS data to Regional Centers can be independent of any IGS agreed upon delivery technology and/or standard. Options currently in use include frame relay, VSAT technology, dedicated phone lines, radio and the internet or combinations thereof. Flexibility in "last mile" communications hardware and protocols between operating agencies and the stations increases the IGS' ability to bring together data from agencies operating stations under their own agencies' disparate missions and requirements. The advent of relatively inexpensive satellite internet service is a possible solution to bring internet access direct to the reference stations. It is possible to consider direct multicast of data from reference stations.

The delivery of the raw data and associated meta-data to the IGS community at large, whether from RC's or direct from station(s) does require an agreed upon delivery

method. The current model of distributing data solely via discrete data centers may not be optimal for a real time environment. Instead a model whereby the data is distributed directly to the end users should be investigated. One such model could be the use of Internet Multicast. Using IP Multicast a server at an RC can multicast data to many users simultaneously thus permitting multiple analysis / data centers to share the same source simultaneously.

The possible drawbacks to the reliance on the internet are centered on security and reliability. As the IGS evolves as an organization providing a number of products and services with an increasing and reliant user base, security to the service and reliability of the service will become critical. For these reasons the IGS must look at redundancy both in station distribution and in the distribution of all data (real time through 24-hr data sets) and products. The use of the public internet, for example, may not be robust enough to ensure 100% data recovery at all recipient sites – (we have all experienced Internet "drop outs") ...

In the near term it would be useful, if those operating real-time networks could provide detailed technical information, on-line, to help facilitate the delivery of real-time data from reference stations to Regional Centers. Further to this the IGS must engage in a discussion of how best to distribute data and products. It will be necessary to agree upon protocols for the delivery (broadcast) of real time data and develop non-proprietary, open sourced standards and tools to ensure robust data delivery.

9.1 Issues / questions to discuss wrt Real Time Communication:
- Dissemination / sharing of technical information for the retrieval of high rate (1HZ) data in real time from reference Station to Regional Data / Network Center;
- Delivery of high rate (1Hz) data in real time to the IGS community (method, protocols, etc.);

Acknowledgements

Reference Material

(1)Fontana, Richard; Wai Cheung; Paul M. Novak; Thomas A. Stansell Jr.: The New L2 Signal; http://www.navcen.uscg.gov/gps/modernization/TheNewL2CivilSignal.pdf

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